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DESIGN OF A SHUNT SOLAR REGULATOR WITH MPPT «DISTURBANCE & OBSERVATION» CONTROL.

Engineering

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ABSTRACT

This work presents the design of a shunt solar regulator used in photovoltaic systems. The shunt solar regulator first allows to adapt batteries with voltages higher than that of the solar panel, then to protect the batteries against the phenomena of overload and deep discharge and finally to ensure the continuation of the maximum power point by the method «perturbation & observation ». Indeed, from the model of the BOOST converter existing in the literature we have developed and calculated its various parameters. The simulations carried out with Matlab/Simulink have made it possible to optimize the production of the PV field and to clarify the fact that the PV field can operate at its maximum power point if it is interfaced by a converter which seeks at all times the maximum power.

KEYWORDS

Shunt regulator, MPPT, P&O, Photovoltaic system, Booster chopper, PI corrector.

INTRODUCTION

In recent decades, sickle energy (oil, gas and coal) has been the main source of energy used in the industry. The latter have contributed to the development of technology. But because of their adverse effects on the atmosphere, their uses are beginning to decline. For example, science has used green energy, commonly known as renewable energy, as the ultimate solution to climate problems. [1] Due to the large fossil energy sources available to our country (Senegal) and the absence of environmental policies, the development of renewable energies has lagged far behind. Today, given the challenges posed by these sustainable sources of energy, their promotion must be one of the main axes of the country's energy and environmental policy. In particular, our country has one of the highest solar deposits in the world, [2] because of its geographical position, Senegal has more than 3,000 hours of sunshine per year on average over a very large part of its territory. [3] The most important source of renewable energy is energy from the sun, which provides either thermal energy or photovoltaic energy.

A photovoltaic generator can operate in a wide range of voltage and output current, but can only deliver maximum power for particular values of current and voltage. Indeed, the characteristic □ = □(□) the generator depends on solar illumination and temperature. These climatic variations cause the maximum power point to fluctuate. This fluctuation allowed a solar regulator to be inserted between the panel and the load. The operating system, controlled static converters to extract the maximum power from the generator. These controls are commonly called MPPT (Maximum Power Point Tracking), which, as its name suggests, tracks the maximum power over time and allows the maximum power to be drawn from the PV panel. [4] This article is presented as follows: operation of the shunt regulator, presentation of the P.O MPPT method, modeling of the shunt chopper, description of the simulation results under MATLAB/SIMULINK.

How The Shunt Regulator Works

The solar shunt regulator increases the solar panel voltage to the battery charge voltage. It will adjust its input voltage to get the maximum power from the solar panels and then convert this energy to meet the different voltage and charge requirements. [5]

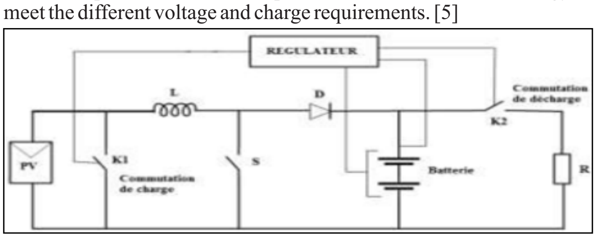

Fig. 1: Shunt policer principle scheme

Switching of the load and discharge switches is presented by an algorithm. The shunt regulator monitors the battery charge by bypassing the photovoltaic module without any risk (K1 switch).

The opening and closing of the K1 short-cooker on the photovoltaic generator is controlled by a hysteresis cycle. For a 48V rated battery, the upper threshold (opening K1) is 52V while the lower threshold (closing K1) is 50V. The opening and closing of the K2 charge connection switch is handled by a second hysteresis cycle. For a 48V rated battery, the upper threshold (closing K2) is 48.5V, while the lower threshold (opening K2) is 47.5V. [6]

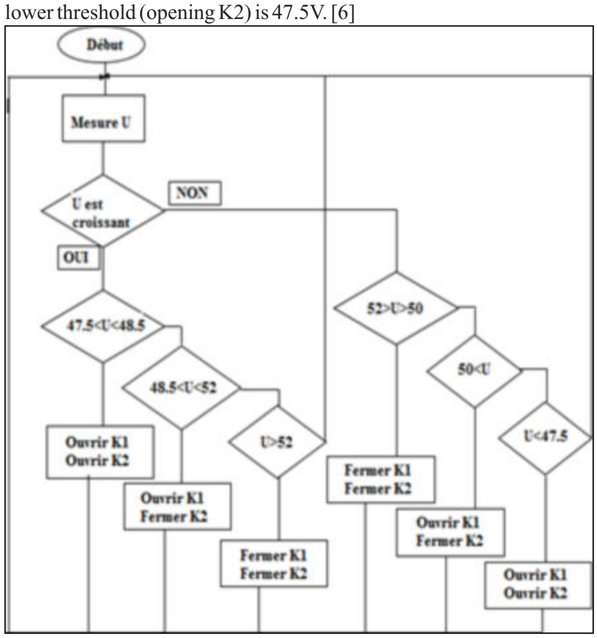

Fig. 2: Load And Unload Switching Algorithm

Understanding P.O MPPT

The MPPT controller or regulator continuously measures and compares the voltage issued by the panel with that of the battery. It then calculates the maximum power level that the panel can deliver to the battery and what the battery can receive.

Based on this power value, it determines the most appropriate voltage (voltage) in order to have the maximum current in the battery. As the name implies, this P&O type method works by disrupting the system, i.e. the voltage V_PV of a small magnitude around its initial value and

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analyzing the behavior of the resultant P_PV. [7] Thus the position of the maximum power point can be inferred. according to whether she believes or decreases. The P&O method is simple, so it provides an easy way to locate the point of operation relative to the PPM, and allows the PPM to be converged to the maximum power.

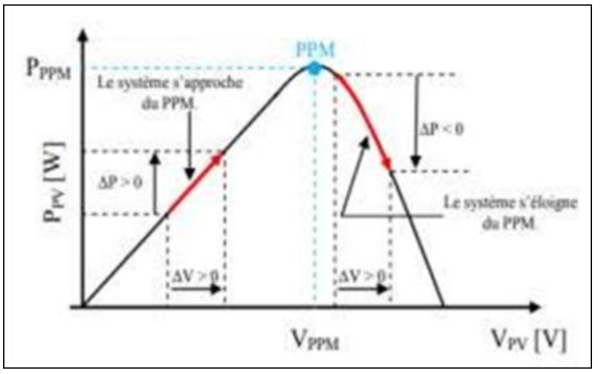


Fig. 3: The PPM's status relative to the point of operation. [8]

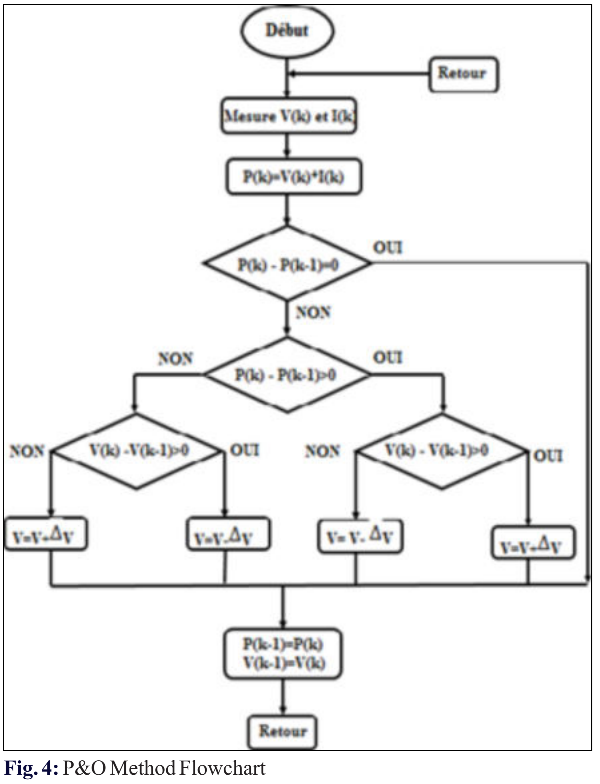


Fig. 4: P&O Method Flowchart

Shunt Hash Modeling

Modeling this converter involves analyzing the different operating sequences that we will assume of durations fixed by the cyclic report command α. There are two operating sequences depending on the state of the switch S. [9]

Structure

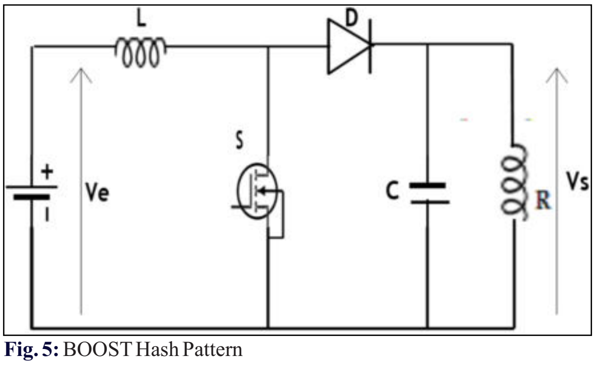


Fig. 5: BOOST Hash Pattern

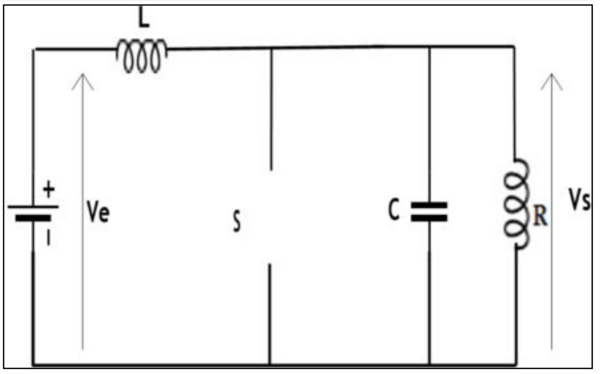


Fig. 7: Sequence 2 Diagram

$$\begin{cases} V_L = V_e - V_s \\ I_C = I_L - \frac{V_s}{R} \end{cases}$$

Operational Principle

- There are 2 different phases of operation depending on the state of the switch S: Active phase: when the S switch is closed and the D switch is open.

During this sequence, the current passing through the L inductance will increase linearly and a W energy is stored in L. The C capacitor provides energy at the R charge.

- The free wheel phase: when the S switch is open and the D switch is closed. During this sequence, the energy stored in the L inductance is returned to the capacitor and the R load. In this phase, the fact that the L inductance is in serial mode with the input voltage source allows for a hover mount. [10]. [11]. [12]

1er Active Phase Case:

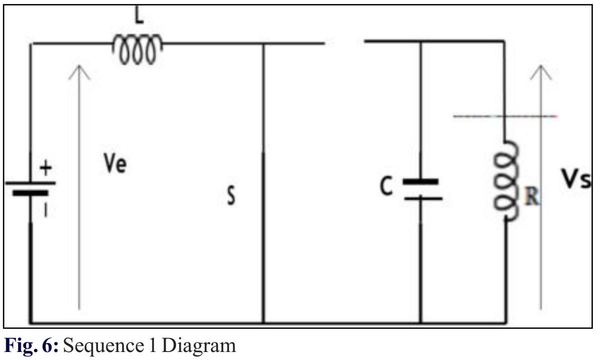


Fig. 6: Sequence 1 Diagram

From the two systems obtained in sequence 1 and 2, we will be able to determine the expressions of the cyclic ratio, of the inductance and of the capacitance of the capacitor. Switches are switched over two half periods:

With:
L : Inductance
C : Capacity
R : Load resistance

Between $0 \le t \le \alpha T$ et $\alpha T \le t \le T$.

$$\int_0^T V_L dt = 0$$

$$\int_0^{\alpha T} V_e dt + \int_{\alpha T}^{T} (V_e - V_s)\, dt = 0$$

$$(V_e \alpha T + (V_e - V_s)(T - \alpha T)) =$$

$$0 (V_e \alpha + (V_e - V_s)(1 - \alpha)) = 0$$

$$V_e - V_s (1 - \alpha) = 0$$

$$\alpha = 1 - \frac{V_e}{V_s}$$

The value of the duty cycle is less than 1. The ripple of current in the coil varies between the minimum value I_{MIN}= 0 and maximum value I_{MAX} =αT

2nd Stage Of Freewheel:

$$\Delta i_L = \frac{1}{2}\left(i_L(\alpha T) - i_L(0)\right)$$

$$V_L = L\frac{di_L}{dt}$$

By integrating:

$$i_L(\alpha T) = \frac{V_e}{L}\alpha T$$

$$\Delta i_L = \frac{1}{2}\frac{V_e}{L}\alpha T$$

$$L = \frac{1}{2}\frac{V_e}{\Delta i_L}\alpha T$$

Either C_{PI}(P) et G(P) the transfer functions of the controller PI and the system index response respectively.

$$C_{PI}(P) = K_P + \frac{1}{c_i P} \quad ;$$

$$G(P) = \frac{1}{1+\tau P}$$

Depending on the undulation of the voltage:

$$C_s = \frac{1}{2}\frac{V_s}{\Delta V_s R}\alpha T$$

We can size the BOOST chopper:

$$V_{pv} = V_e = 12V; V_s = 48V;$$

$$f_s = 20KHz; \Delta V_s = 0.3\,V;$$

$$\Delta i_L = 0.1A; R = 100\Omega$$

$$\alpha = 1 - \frac{12}{48}$$

$$\alpha = 0.75$$

$$L = \frac{1}{2} * \frac{12}{0.1 * 20000} * 0.75$$

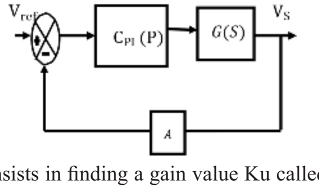
$$L = 2.25\ \mathrm{mH}$$

$$C_s = \frac{1}{2} * \frac{48}{0.3 * 100 * 20000} * 0.75$$

$$C_s = 30\mu F$$

K_P parameters and Ki of the corrcector are determined from the so-called Ziegler- Nichols method or from a simulated chart on Matlab/Simulink.

Determining PI Corrector Parameters



This method consists in finding a gain value Ku called ultimate gain and itscorresponding period Tu La procedure test la suivante :

Initially, we set K_i= 0 and we vary the value of K_P for our closed loop regulator PI. Example: K_P=1 is given, and this value is incremented (i.e. put 1 and so on) forever K_u= 0.

The advantage is to look for what value of K_P, the signal remains stable. The output of the regulator block, i.e. the common block K_P and K_i, is visualized on scope to.

Table. 1: Determination of K_P and K_i

Type Controller	K_P	K_i
PI	0.45 K_P	0.83 T_u

The battery voltage used has a nominal voltage of 48V and a capacity of 100 Ah. A resistive load of 100 Ω is used for the simulation. The calculation of the regulation loop gave the following values of the corrector: K_P= 2.25 Ki= 0.058; and K_u= 5

Description Of Simulation Results Under MATLAB/SIMULINK

The simulation under Matlab/Simulink allowed us to obtain the results presented below. The search for the maximum power point is illustrated in Fig. 8, where a disturbance corresponding to a variation of the irradiation causes a variation of the power produced. Both powers are evolving at the same time. And this shows us that the role of the MPPT is well secured during the charge; but for the discharge MPPT does not intervene too much. The relatively small error between the reference power and that produced by the photovoltaic generator illustrates the performance of the regulator.

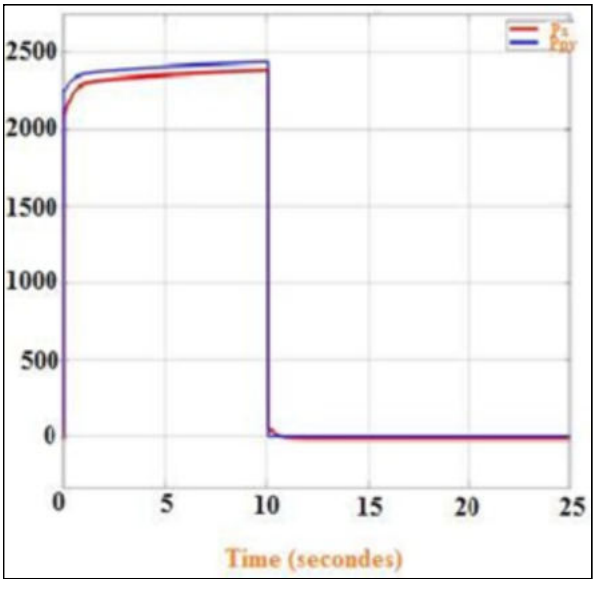


Fig. 8: Evolution of panel power and battery power Caption:

Solar Panel Power P_{PV}
Battery power P_S

The evolution of the voltage and of the current at the terminals of the battery in charge and discharge is illustrated respectively by FIGS. 9 and 10. From A to B the voltage and the current increase: it is the charge and from B to C they decrease: it's the dump.

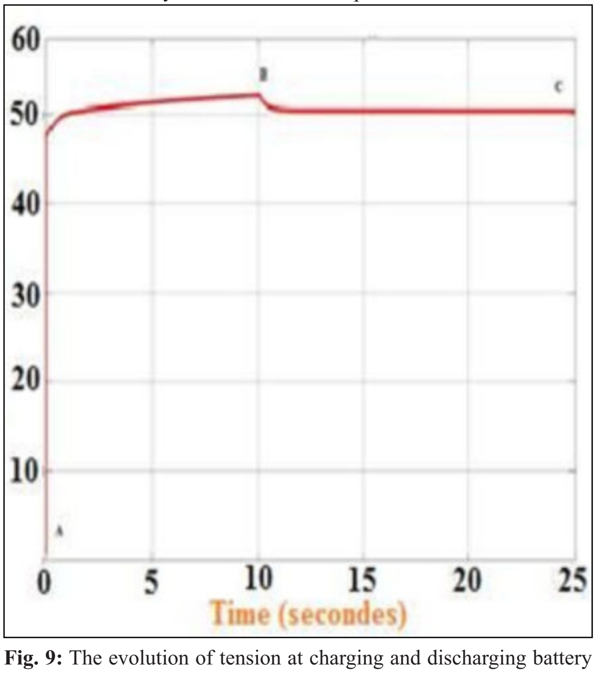


Fig. 9: The evolution of tension at charging and discharging battery terminals

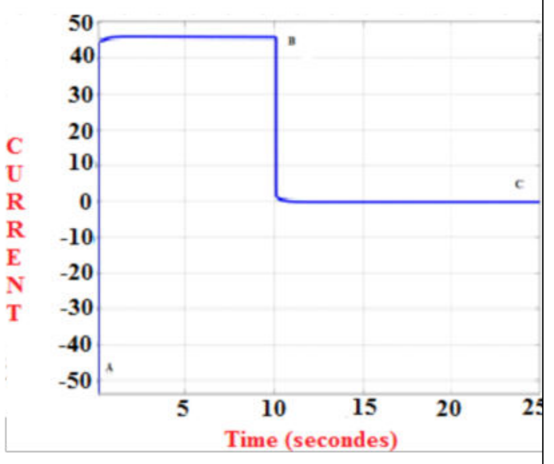


Fig. 10: The evolution of the current atthe terminals of the battery in charge and in discharge

Fig. 12 Shows The Behavior Of MPPT When The Load Is Varied And Irradiation Is Maintained Constant. There Is A Slight.

MPPT when the system is disrupted. Here we disturbed the system by acting on the irradiation and keeping the load constant. We note that the MPPT always responds in such a way that both powers grow at the sometime.

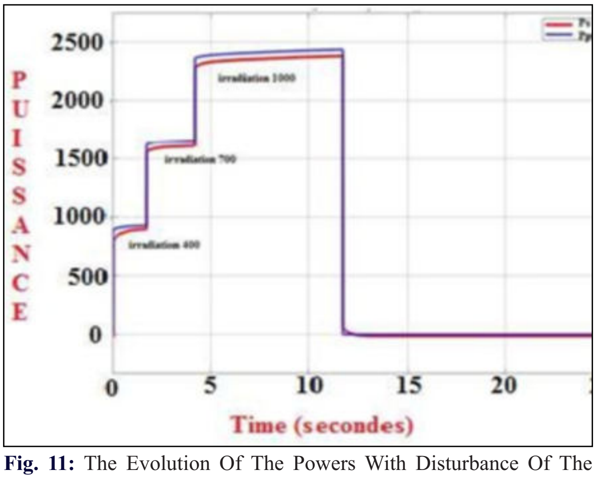


Fig. 11: The Evolution Of The Powers With Disturbance Of The Irradiation

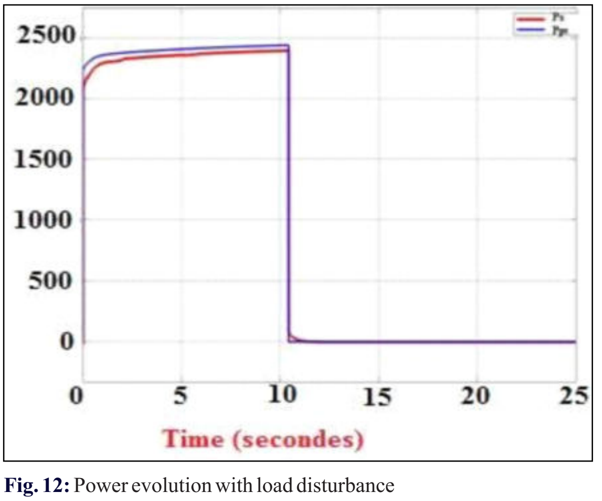


Fig. 12: Power evolution with load disturbance

CONCLUSION

This research allowed the design of a shunt regulator. The simulation results were obtained in the case where the switches controlling the load and the short-circuit of the solar panel are respectively closed and open. These results showed that the regulator has good regulation capacity. The switch control is manual.

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